ENTOMOLOGICAL NEWS

FEBRUARY 1945

Vol. LVI **No. 2**

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PUBLISHED MONTHLY, EXCEPT AUGUST AND SEPTEMBER, BY

THE AMERICAN ENTOMOLOGICAL SOCIETY

PRINCE AND LEMON STS., LANCASTER, PA.

AND

THE ACADEMY OF NATURAL SCIENCES, PHILADELPHIA 3, PA.

Subscription, per yearly volume of ten numbers: $3.00 domestic; $3.30 foreign; $3.15 Canada. Entered as second-class matter April 19, 1943, at the post office at Lancaster, Pa., under the Act of March 3, 1879. Acceptance for mailing at the special rate of postage prescribed for in Section 1, Act of October 3, 1917, authorized January 15, 1921.

ENTOMOLOGICAL NEWS

ENTOMOLOGICAL NEWS is published monthly, excepting August and September, by The American Entomological Society at 1900 Race Street, Philadelphia 3, Pa., U. S. A.

PHILIP P. CALVERT, Editor Emeritus. Editorial Staff: E. T. CRESSON, JR., E. J. F. MARX, J. A. G. REHN, A. G. RICHARDS, JR., and R. G. SCHMIEDER.

Subscription price, per yearly volume of 10 numbers: Domestic, $3.00; Foreign, $3.30; Canada, $3.15—U. S. Currency.

SUBSCRIPTIONS, ADVERTISEMENTS: All communications and remittances to be addressed to **ENTOMOLOGICAL NEWS, 1900 Race Street, Philadelphia 3, Pa.**

ADVERTISING RATES: Full width of page. Payments in advance.

	1 Inch	2 Inches	3 Inches	6 Inches
One Issue	$1.00	$ 1.90	$ 2.75	$ 4.80
Five Issues	4.50	8.50	12.00	21.00
Ten Issues	8.00	15.00	21.00	36.00

MANUSCRIPTS and all communications concerning same should be addressed to **A. G. Richards, Jr., Zoological Laboratory, University of Pennsylvania, Philadelphia 4, Pa.**

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aristodemus, ponceana, A. ponceana MARCH.

ENTOMOLOGICAL NEWS

VOL. LVI FEBRUARY, 1945 No. 2

Papilio aristodemus ponceana Schaus (Lepidoptera: Papilionidae)

W. F. HENDERSON,* Chicago, Illinois

In the winter of 1938 the writer spent a very pleasant hour looking over the collection of Mr. and Mrs. C. N. Grimshawe in Miami, Florida. Mrs. Grimshawe showed a series of *Papilio aristodemus ponceana* Schaus and told a very interesting story about this sub-species. Since the destructive hurricane of 1935, no *ponceanas* had been seen up to the time of this visit and it was feared that this sub-species might be extinct.

Later the writer had an opportunity to acquire five specimens of *ponceana* and it occurred to him that it would be interesting to assemble the known data concerning this sub-species. Correspondence soon revealed a most fortunate fact, viz., that *ponceana* had been seen and taken on three occasions since 1939. Evidently it is not extinct as was once feared, although it does seem to be very rare.

Papillo ponceana was first taken by William Schaus in May 1898 near Miami. He described it in 1911 (1), indicating that it is allied to *P. aristodemus* Esper and to *P. temenes* Godart. The types are in the U. S. National Museum. *Papilio aristodemus* was first described by Esper in 1794 (2). *P. temenes* was described in 1819 by Godart (3) who makes the very general statement, "It is found in the Antilles and in North America."

In 1917, Barnes and McDunnough (4) listed this species as follows:

* Present address, 9833 S. Hamilton Avenue, Chicago, Illinois.

12 *aristodemus* Esper
a *ponceana* Schaus

Barnes and Benjamin (5) listed it in the same way, as No. 13 in their diurnal list in 1926. This relationship has been continued, although in 1930, Holland (6) argued that *ponceana* should be considered a distinct and true species. He listed it and figured it as *ponceanus* in the second edition of his Butterfly Book in 1931 (7).

Bates (8) answered Holland's statement in 1934, apparently preferring to accept the sub-specific status as set forth in Barnes' check list. When McDunnough (9) published a revision of the check list in 1938, he again placed *ponceana* as a sub-species of *aristodemus*. In all the collections contacted where specimens of *ponceana* occur, this status seems to be the accepted one.

An article describing the finding of *ponceana* and also its early stages was written by Mrs. F. M. Grimshawe in Nature Magazine (10) in December 1940. Of all the known specimens of *ponceana* (24 to date), seventeen of these have been either collected or reared by the Grimshawes. They deserve much credit for their contribution to our knowledge of this sub-species.

The writer has assembled all of the data he has been able to find in regard to *ponceana*. There may be other specimens, now unknown, in other collections, and if this is true, the data concerning these should be added. The accompanying table sets forth the data collected.

Summary

Papilio aristodemus ponceana Schaus is not extinct. Twenty-four specimens have been accounted for in American collections. The available data concerning *ponceana* have been tabulated.

The author is grateful to all of those who have cooperated with him in assembling these data.

No.	Sex	Collecting Data			Present Possessor
		Locality	Date	Collector	
1	♂	Miami, Florida	May 1898	W. Schaus	Type; U. S. National Museum
2	♀	Miami, Florida	May 1898	W. Schaus	Type; U. S. National Museum
3	♀	Cuba (Error; prob. Fla.)	1899–1900	W. Schaus *	Amer. Museum Nat. Hist., N. Y.
4	♀	Cocoanut Grove, Fla.	5–31–24	G. B. Fairchild	Mus. Compar. Zool., Cambridge, Mass.
5	♀	Lower Matecombe Key, Fla.	5–19–35	C. N. Grimshawe	Amer. Museum Nat. Hist., N. Y.
6	♀	Lower Matecombe Key, Fla.	5–26–35	C. N. Grimshawe	Amer. Museum Nat. Hist., N. Y.
7	♂	Lower Matecombe Key, Fla.	6–1–35	C. N. Grimshawe	Amer. Museum Nat. Hist., N. Y.
8	♂	Lower Matecombe Key, Fla.	6–1–35	C. N. Grimshawe	Amer. Museum Nat. Hist., N. Y.
9	♀	Lower Matecombe Key, Fla.	6–1–35	C. N. Grimshawe	Amer. Museum Nat. Hist., N. Y.
10	♂	Lower Matecombe Key, Fla.	6–2–35	C. N. Grimshawe	W. F. Henderson, Chicago, Ill.
11	♀	Lower Matecombe Key, Fla.	6–9–35	C. N. Grimshawe	Amer. Museum Nat. Hist., N. Y.
12	♀	Lower Matecombe Key, Fla.	6–9–35	C. N. Grimshawe	Amer. Museum Nat. Hist., N. Y.
13	♂	Lower Matecombe Key, Fla.	6–10–35	C. N. Grimshawe	W. F. Henderson, Chicago, Ill.
14	♀	Lower Matecombe Key, Fla.	6–13–35	C. N. Grimshawe	W. F. Henderson, Chicago, Ill.
15	♂	Lower Matecombe Key, Fla.	6–18–35	C. N. Grimshawe	Stallings-Turner Coll., Caldwell, Kas.
16	♂	Lower Matecombe Key, Fla.	6–23–35	C. N. Grimshawe	Amer. Museum Nat. Hist., N. Y.
17	♀	Lower Matecombe Key, Fla.	8–11–35	C. N. Grimshawe	Amer. Museum Nat. Hist., N. Y.
18	♂	Lower Matecombe Key Bred	4–13–36	C. N. Grimshawe	W. F. Henderson, Chicago, Ill.
19	♀	Lower Matecombe Key Bred	5–13–36	C. N. Grimshawe	Amer. Museum Nat. Hist., N. Y.
20	♀	Lower Matecombe Key Bred	6–1–36	C. N. Grimshawe	Stallings-Turner Coll., Caldwell, Kas.
21	♀	Lower Matecombe Key Bred	5–15–37	C. N. Grimshawe	W. F. Henderson, Chicago, Ill.
22	♂	Key Largo, Florida	6–4–40	D. F. Berry	D. F. Berry, Orlando, Fla.
23	♀	Key Largo, Florida	6–5–40	Mrs. D. F. Berry	C. F. Dos Passos, Mendham, N. J.
24	—	Matheson Hammock, Fla.	1943	R. Chermock	F. H. Chermock, Butler, Pa.

* This specimen bears a datum "Jacob Doll," but Mr. W. P. Comstock of the American Museum of Nat Hist. advises that it was probably taken by Schaus, near Miami.

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The Feeding Habits of Uranotaenia lowii Theobald (Diptera: Culicidae)

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Army of the United States

The host preferences of mosquitoes important to man as carriers of pathogenic organisms have long been investigated. However, several large genera and parts of others are not known to include disease vectors, and little dependable information on these mosquitoes exists. Instead, many casual notes have appeared, containing presumed or suspected facts. The genus *Uranotaenia* L.-Arr. stands out among the neglected groups, and the present paper deals with a species of that genus.

[1] I am grateful to Mr. M. Graham Netting of the Carnegie Museum for identification of the amphibians mentioned in this paper; to Mr. Robert Alrutz for obtaining these determinations from Mr. Netting and for records of *U. lowii* biting in the field; and to my many entomological associates for helpful suggestions during the preparation of the manuscript.

Over twenty species of *Uranotaenia* are known from British India, and yet the knowledge of their bionomics was summarized by Barraud (1934) thus: "Little is known of the habits of the adults; they do not appear to attack man to any extent." Edwards (1941) in his classic study of African culicines discusses 25 species and 5 varieties of *Uranotaenia*. He states: "Little is known of the habits of adult members of this genus. None of the African species has been observed to suck blood . . ." A clue to the feeding habits of one species is found by Davis and Philip (1931). In Africa precipitin tests were made with 66 *U. annulata* Theob. with antihuman and anti-chicken sera. All were negative for human blood, and 7 were positive for chicken blood. These writers state that: "The *Uranotaenia* were poorly blooded on the whole; the samples were small and considerably altered in most cases." This host indication for *U. annulata* awaits confirmation by observations.

Uranotaenia sapphirina (O.-S.) and *U. lowii* Theob. are the representatives of the genus in the eastern half of the United States. In correspondence, Mr. G. H. Bradley has informed me: "I have observed both of these species to alight on man and move around as if preparing to bite, however, no piercing of the skin ever was noted and it appeared as if they were merely lapping up perspiration." Rozeboom (1942) writes: "Rarely they were observed biting a horse or man" in Oklahoma. Headley (1921) believes that *sapphirina* does not take blood. Dyar (1922) relates that: "While every attempt possible was made to try to get females to suck blood, the writer has never observed a single one biting." A contradictory statement appears in his later work (1928), when he states: "The adults will bite under favorable conditions but are very seldom met with."

Even less is written about *U. lowii*. Hinman (1935) finds that: "Under no conditions have they been induced to suck blood." King, Bradley, and McNeel (1939) concisely conclude: "The adults are rarely seen and are not known to bite humans." Theobald (1903) quotes Hewlett, who, in a statement of questionable accuracy, reports *U. lowii* rare in Trinidad and biting (man) severely.

The first known observation of *Uranotaenia lowii* taking blood was made in August, 1944, during general insect collecting at lights near New Orleans, Louisiana. It was feeding on a tree frog (*Hyla cinerea*) under a light. In order to obtain further information on the host preferences, a series of biting tests was undertaken in the laboratory. *U. lowii* was very abundant and provided adequate living material for the investigations. Amphibians and reptiles were plentiful and those used for study were collected during field trips. All mosquitoes and hosts used were taken near Harahan, Jefferson Parish, Louisiana, and all biting tests were made there.

Equipment and Methods

The *U. lowii* females desired for the tests were collected at lights. The mosquitoes were taken alive into the laboratory and their identity checked with the aid of a dissecting microscope. The presence of white distal segments on the hind tarsi and the absence of blue-purple iridescence on the mid-mesonotal longitudinal line easily separate *U. lowii* from the other Louisiana species of *Uranotaenia, U. sapphirina.* The latter occurred in the same area where *U. lowii* was being collected, but none was found at light in the vicinity of the laboratory. About one mile to the east, beside the Mississippi River, the two species were taken in a light trap in nearly equal numbers. Male *lowii* were rare at light.

The cage used for the biting tests was a one-foot cube with a solid wood bottom and sides of 16-mesh hardware cloth fastened to a wooden frame. To observe biting mosquitoes a Spencer binocular microscope was used with a 9 × eyepiece and 1 ×, 2 ×, and 3 × objectives in a revolving mount. The barrels of the instrument were lifted from the upright of the frame of the microscope, and manual support and focussing, rather than mechanical, had to be used. The objective could then be brought as near the side of the cage as desired. Objects more than four inches from the objective were out of focus. Consequently, the animals being tested had to be near the side of the cage. They were placed in the cage through the cloth sleeve

and were placed near the side and allowed to become quiet before mosquitoes were introduced.

U. lowii showed no desire to feed under a direct light. A cloth placed to reduce the amount of illumination entering the cage diffused the light, and the mosquitoes quickly flew to the lower part of the cage and discovered any hosts present. Once an individual had begun to feed, the cloth could be removed without interrupting the process.

Biting Habits Observed

The mosquitoes, if placed with an unattractive animal, gave it no attention at any time. On the other hand, when a suitable host was present, *U. lowii* quickly showed interest, and some soon began to feed. Usually the tiny culicines did not fly to the body of the host. Most often, they lit on the floor near the animal and walked toward it. On contacting the animal, *U. lowii* placed the front legs and proboscis against the host, rested on the front and middle legs, and slowly, alternately rotated the elevated, white-footed hind legs. As many as five minutes were consumed in tapping over an area of the skin with the flexible proboscis. During the process, some individuals moved up onto the body of the host, although most remained on the floor. The tapping seemed to be the means of locating the most superficial capillaries of the host.[2] At length, the mosquito inserted the proboscis and began feeding in the above-described position, leaning forward against the host and continuing to rotate the hind legs. This practice of resting beside the host, rather than on it, while feeding, though common with *U. lowii,* must be somewhat unusual.

With most *Uranotaenia lowii* females captured for use in the biting tests, the abdomen contained varying amounts of a pale yellow fluid, possibly a plant juice. Some with distended abdomens took a blood meal as readily as those only slightly fed. One of the first *U. lowii* whose feeding was watched was full of

[2] However, Gordon and Lumsden (1939) believe, from their observations of *Aedes aegypti* (L.), that at least the fascicle of the proboscis is incapable of sensing the location of blood vessels.

the pale liquid before being placed with a toad. It fed unusually long, and after about five minutes it began issuing tiny drops of the fluid from its anus. For fully ten minutes these fell, apparently forced out by the blood entering the stomach as the mosquito continued to feed. When the proboscis was withdrawn, the stomach was red and greatly distended. It may be that *U. lowii* takes the juices for its own sustenance, but requires blood to produce eggs; in which case, when a blood meal is secured, the less valuable plant juices or animal excretions are forced out.

Host Preferences

Homo sapiens L. Twelve female *Psorophora confinnis* (L.-Arr.) and twenty female *Uranotaenia lowii* were placed in the cage and the writer's bare arm was thrust in through the sleeve. The *P. confinnis* quickly attacked the arm. The *U. lowii* rested as readily on the arm as on parts of the cage, but none evidenced any desire to feed on man. A few minutes later these *lowii* fed on a toad.

Terrapene carolina (L.). Ten *U. lowii* were introduced into the cage with the tortoise. None had tried to feed after 30 minutes. Then ten more were added. During the next 30 minutes none of the twenty fed. At the same time ten *U. lowii* were placed with two *Bufo valliceps* in a cage under similar conditions. Several of the *U. lowii* immediately approached the toads and were soon feeding. Their lack of response to the presence of the tortoise was clear, while they fed normally on a known host.

Leiolopisma laterale (Say). Twenty *U. lowii* were placed in the cage with three of these Ground Lizards, which are very numerous in southern Louisiana. No lizards had been attacked after 100 minutes. Ten *lowii* were simultaneously released into a similar cage containing two toads, and as in all other controls used, the *lowii* fed eagerly on the toads. This test was twice repeated with the same results.

Anolis carolinensis Voigt. On three separate occasions twenty *U. lowii* were placed in a cage with an American Chameleon, for periods varying from 45 to 100 minutes, and no

desire to bite was shown by the mosquitoes. The toads in the nearby cage were readily attacked in each of these tests.

Rana sphenocephala (Cope). A single *U. lowii* was taken feeding on the amphibian under field conditions, but no laboratory tests were made with this Southern Leopard Frog.

Hyla c. cinerea (Schneider). *U. lowii* were collected in the field feeding on this common tree frog on two occasions. Five large *H. cinerea* were placed in the cage and twenty *U. lowii* females were introduced with them. Some difficulty was experienced when the tree frogs ate five of the twenty mosquitoes, but the latter avoided the attention of the amphibians after becoming accustomed to the cage. Within 30 minutes all of the surviving mosquitoes had approached the Hylae, and at least three had fed to repletion. The thigh of the hind legs of the frogs was the object of all observed feedings. Several *U. lowii* flew to a patch of urine discharged by a *Hyla,* and some seemed to feed briefly on the fluid. Twelve *Psorophora confinnis* introduced with the *U. lowii* showed no desire to feed on the amphibians, and rested most of the time on the ceiling of the cage. (See below under *Bufo valliceps* for further notes on *Hyla.*)

Bufo valliceps Weigmann. One *U. lowii* was collected in the field from this, the Mexican Toad, and several were seen biting the species on another occasion. This species was clearly a favorite host of *U. lowii* in southern Louisiana. In the laboratory ten female *lowii* were placed in a cage containing two small *Bufo valliceps* and an equal-sized *Hyla cinerea.* After 75 minutes the ten *U. lowii* were collected in a chloroform tube and examined. Eight had taken blood meals in the cage. The *Hyla* was carefully watched throughout the 75 minutes, and only one *lowii* fed on it. Therefore, seven of the eight which took blood meals preferred the two *Bufo* to the *Hyla.* These *Uranotaenia* seemed to evidence such a preference for *B. valliceps* that the toad was used as the comparison species in the controls run with the tests on other animals. These controls are mentioned under foregoing species.

(*To be continued*)

Statement on DDT by the American Association of Economic Entomologists

At the annual meetings of the two national entomological societies in New York, December 13–15, 1944, most of the papers and discussions involved recent experimental work with DDT. At the end of the meetings the American Association of Economic Entomologists adopted the following statement to summarize the results of various research projects and to correct "misunderstanding, over-optimism and distorted impressions." This statement seems of sufficient general interest to repeat in full here. THE EDITORS.

"We feel that never in the history of entomology has a chemical been discovered that offers such promise to mankind for relief from his insect problems as DDT. There are limitations and qualifications, however.

"Subject to these, this promise covers three chief fields: public health, household comfort, and agriculture. As public health we include control of the insects which carry diseases that have scourged humanity, such as malaria, typhus and yellow fever. Household comfort is taken to cover such things as flies, fleas, bedbugs and mosquitoes. Agriculture includes not only farms, gardens and orchards but forests, livestock and poultry.

"In the public health field DDT insecticides are so much more effective than previous weapons against malaria mosquitoes that for the first time there is a practical hope for eradicating that disease from this country. DDT proved in Italy that it is the first and only practical control for typhus. In the household field its amazing lasting effect promises relief for months from flies, mosquitoes and fleas. In the case of bedbugs, eradication from the American home has become a possibility.

"In agriculture, it is promising against a wide variety of destructive pests. These include most potato insects, many orchard and vineyard pests, numerous vegetable insects, as well as the chief insect enemies of vitally important seed crops. It appears to be effective against the pink bollworm and outstanding against the Japanese beetle, two of our worst imported pests.

It promises also a more practical control of the pests which ravage thousands of square miles of forest, and against many of those which harass livestock.

"DDT will not kill all the important insect pects. It will kill many beneficial insects which are allies of mankind against the destructive species. Because of its toxicity to a wide variety of insects, its large-scale use might create problems which do not now exist. To illustrate, it is a superior insecticide for control of codling moth on apples, but in some sections at least will kill certain natural enemies and thus release other insects which may then become major problems.

"The research reports emphasize that we have not had time to develop entirely satisfactory mixtures and dosages of DDT insecticides, nor the method and timing of application for many possible uses. Modern agricultural pest control often requires mixing several materials in combination treatments, and we know little of DDT's compatibility with many of these others. Researches thus far were made with a material which was produced under pressure for military needs, and which is not necessarily the best form for agriculture.

"We do not know enough about effects on plants, animals and soils. While most plants were not harmed by DDT insecticides in the experiments, injury to squash, corn, tomatoes and possibly fruit trees was reported. DDT is toxic to animal life when large amounts are taken internally or absorbed through the skin from oil solutions, but reports indicate a reasonable margin of safety. In the light of our present knowledge, heavy deposits on edible parts of plants should be avoided. Reports show definite toxicity to cold-blooded animal life including fish and frogs. There has not been time to learn the possible cumulative effects on soils.

"More and larger-scale experimentation is needed. Enough DDT for such research in 1945 should be provided."

Raids of Formica sanguinea Latr. (Hym., Formicidae) [1]

W. V. Balduf, University of Illinois

During the years 1938, 1940 and 1944, I took advantage of chance opportunities to observe twelve raids by four separate colonies of the red slave ant, *Formica sanguinea* Latr. found on the University campus at Urbana. The identity of the subspecies of *sanguinea* and the ants raided by them in this area is suggested in the studies made by Smith (1927). He established that subspecies *rubicunda* Emery and *subintegra* Emery occur here, the former common, and that they pillaged the larvae and pupae, chiefly of *Formica fusca subsericea* Say, but also raided the nests of *F. neogogates* Em. and, in one case, that of *Aphaenogaster fulva* Roger. Concerning the latter ant, Smith remarked "the brood they (*sanguinea*) pillage must be eaten shortly afterwards for no one has yet observed a mixed colony of these Myrmicine and Formicine ants."

My contribution on *sanguinea* is divided into two parts,—first an account of a raid observed on July 4, 1944, and second, a number of observations on diverse activities.

I discovered the above mentioned raid in progress near McKinley Hospital at 4:15 P.M. The line of scurrying red workers had not yet reached the *fusca* nest when I came upon it. Without delay they plunged into the entrances and in a very short time the advance individuals reappeared with booty in their jaws and sped on the homeward trip. In a later phase of the first round trip, many of the advanced pillagers had already borne their *fusca* captives home and descended into their subterranean nest, while the hinder part of the column was still approaching home. Then several minutes passed in which it seemed the raid was about to end; where upon the reds again poured from their nest in numbers as large as those that made the first trip I observed. These traversed precisely the same

[1] Contribution Number 243 from the entomological laboratories of the University of Illinois.

course and entered the same *fusca* nest as before. The last individuals to leave the pillaged nest on the second observed trip carried no *fuscas* in their jaws. No evidence of a third assault was seen, hence the raided colony appeared to have lost its entire population of larvae and pupae to their marauding relative. Although only two round trips were observed, it is possible that the raiders had already completed one or more invasions before I came on the scene. This possibility is suggested by the fact that the entrances were not plugged, so the reds entered without delay on the first observed trip.

The distance covered in the two trips was around 636 feet, and the total traveling time was approximately 115 minutes. On this basis, the average speed was about 5.5 feet per minute. The raiding workers pressed on at a maximum rate at all times. They crossed a varied terrain that included a short-cut lawn, a concrete walk, a stretch of crushed gravel and a debris-covered woods floor. Now and then an individual left the main trail but promptly rejoined the racing column after a brief lateral run.

By taking a fixed position along the trail I was able to count 1281 immature *fuscas* carried from their nest. The individuals removed consisted of a few callows and many pupae and larvae, the latter representing various sizes or instars. In general the pupae and larger larvae were transported in the earlier phase of the raid. Toward the end of the second round, many reds bore larvae so small it was not always easy to determine whether they carried booty. However, pupae still appeared in small numbers even near the end of the raid. Since the large majority of the ants carried *fuscas,* the raiding army is estimated to have numbered approximately 650 workers. In the instance reported by Parker, the *sanguineas* transported about 12,800 immature *fuscas* in a total working time of 18 hours distributed over three consecutive days in August.

Diverse Activities of *F. sanguinea*

At 5:30 P.M. of July 24, 1938, more than 100 red workers of a colony near the Old Agricultural Building were seen milling

excitedly over the site of a *fusca* nest. This delay in entering the nest may have been due to obstructing plugs which *fusca* was found by Talbot and Kennedy to insert into the entrances.

In late afternoon of July 19, 30 workers of the same colony were discovered spreading in an irregular and, it seemed, planless manner from their nest site. This activity probably represented exploration for *fusca* nests to be raided later.

This colony plundered a nest of *fusca* only eight feet from its home site on July 29. There seemed to be but one entrance to the black nest, and its size did not permit the reds to enter and emerge simultaneously. When a red worker appeared at the exit from within the nest, she pushed her captive *fusca* larva or pupa partly out through the hole. At this instant, the captive was seized, or possibly stolen, by another worker waiting outside, which then carried the *fusca* home. This performance was seen to occur several times. In the scheme of *sanguinea,* the worker is believed usually to do its part in a raid without such aid.

About 650 red workers of the same colony took part in a raid observed on July 24. On the basis of partial counts, I concluded only 30 to 40 per cent of this number found *fuscas* to carry home. Similarly low per cents of the workers returned home without booty also on other occasions. Because the red nest was situated only five to 20 feet from the *fusca* nests known to be invaded, these probably suffered repeated raids that kept their populations reduced to small numbers. The black adults offered only slight, if any, direct resistance to the observed onsets of the reds.

Upon depositing their captives in the subterranean chambers of their nests, some of the red workers reappeared, in a few instances, above the nest site and gathered in small knots among the grasses and a foot or so toward the location of the *fusca* nest lately raided. In 15 or 20 minutes, these groups dissolved and the ants returned into the nest. Are such reappearances to be interpreted as incipient second raids? Had these ants met with other workers still returning home with booty, would they have made another trip to the *fusca* nest?

On August 7, 1938, I discovered an army of red workers loitering and roaming aimlessly over a lawn at Lafayette, Illinois. Their nest was adjacent to the foundation of a house, whose owner had poured hot water on the nest three days earlier. Presumably the reds were out on a raid at the time the nest received this treatment, and were now a homeless wandering band. At one time in the afternoon, they milled slowly near the old nest site, and later were seen travelling indifferently away in a loose file, following a path over which I had seen a red colony make a normal raid in 1935.

Kennedy states the flight time of *sanguinea* has varied, according to recorded cases, from about July 6 to August 3. I saw three winged adults crawling over the site of the colony at the Old Agricultural Building at 2:00 P.M. of July 22, 1938. They were accompanied by four apterous reds and a larger number of worker *fuscas*.

The earliest observed raids of the summer were made on July 4 and 5, 1944, and the latest on September 3, 1940. Invariably the raids occurred on warm sunny days. The nests were situated in regularly-mowed lawns and in direct sunlight.

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The Mechanics of Digestion in the Calliphorid Flies

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The first thorough description of the digestive system of the Calliphoridae was made by Lowne, who, in 1890, published a two volume work on *Calliphora erythrocephala*. Recently (1934) Graham-Smith has treated the same subject in even greater detail. Wigglesworth, both in a separate paper (1929) and in his recent book on insect physiology (1940) has also discussed this matter, especially with reference to the function of the proventriculus. Others who have contributed to the discussion are Hewitt (1907), Giles (1906), Patton and Cragg (1913), Patton and Evans (1929) and Snodgrass (1944). The bulk of the present paper has been drawn from the work of the authors cited. Some observations of my own on *Lucilia sericata* and *Cynomyia cadaverina* have also contributed to this discussion.

The digestive system of the calliphorid flies is one of the most specialized groups of organs known. Food is ingested, most of it in a liquid form, into a thin-walled tube which extends from the tip of the proboscis to the proximal part of the abdomen, within which it is expanded to form a bilobed pouch capable of considerable distension. This organ, the crop, is exclusively a storage place for ingested food.

Near the anterior wall of the thorax the oesophagus bifurcates: the ventral branch being that continuous with the crop, the dorsal passing almost immediately into the *proventriculus*. Posterior to the proventriculus the digestive tube exhibits a narrow constriction, then widens into the *mid-intestine*. The anterior portion of this mid-gut, which is also its widest part, lies in the thorax, but it continues into the abdomen where it is much coiled. As in other insects, its posterior termination is marked by the attachment of malpighian tubules: four of them in this case. The anterior two-thirds of the *mid-intestine* is is much narrower than the mid-gut, but posteriorly it expands

to form the *rectal sack,* a peculiar structure which narrows posteriorly until it terminates in the *anus.*

Before considering the functions of these various parts it is necessary to call attention to some details of structure. Dorsally a short band of muscle connects the proventriculus with the anterior wall of the thorax. The paired *salivary glands,* which are long, coiled, and very delicate, are attached to the sides of the proventriculus. The structure of the proventriculus is too complex for analysis here, but essentially it consists of an invaginated plug perforated by the lumen of the dorsal branch of the oesophagus, and an outer wall which is heavily muscular. The anterior portion of the mid-gut appears almost nodular as a result of the fact that the muscular layer forms a reticulum with recangular interstices through which the epithelial lining protrudes. Posteriorly the muscular layer becomes practically continuous so that the outer wall is smooth. About mid-way of the narrow part of the hind-gut is a valve bearing chitinous spines. The rectal sacks bears four invaginated *rectal papillae* of considerable complexity and richly supplied with tracheae.

Since the oesophagus, crop, and proventriculus are of stomodeal origin, they are lined with a chitinous intima which is continuous with the exoskeleton of the fly. The intima which lines the oesophagus and crop, although very thin and capable of much extension, is practically impermeable, even to molecular solutions. This may be demonstrated by ligating the oesophagus just anterior to the crop when the latter is distended by a sugar solution imbibed by the fly. The excised organ may be immersed in distilled water for several days without exhibiting any shrinkage, and without successive samples of the water giving a positive test for sugar. An excised crop filled with water may be immersed in a molar solution of sodium chloride indefinitely without collapsing. The crop is obviously a storage organ only; so far as absorption is concerned, any material it contains might just as well be outside of the body.

Although efforts have been made to demonstrate that the proventriculus acts as a *valve* between the oesophagus and mid-

gut, both Graham-Smith and Wigglesworth are of the opinion that its sole function is that of forming the peritrophic membrane. That a peritrophic membrane exists, and that it is formed in the proventriculus there can be no doubt. This membrane, unlike that lining the crop, is highly permeable, and functions, probably, to protect the walls of the mid-gut from abrasion.

A sphincter is present in the short, dorsal branch of the oesophagus just anterior to the proventriculus. I have observed this sphincter relax at irregular intervals, allowing the passage of material into the mid-gut. Two other oesophageal sphincters are present: one just anterior to the bifurcation, the other posterior to it in the wall of the oesophagus leading to the crop. By closing the valve on the dorsal branch food may be directed into the crop, or, by reverse peristalsis the fly may regurgitate liquid. Constriction of the valve just anterior to the bifurcation, with simultaneous relaxation of the other sphincters, allows food to pass from the crop to the mid-gut.

Unlike those of the crop, the walls of the mid-gut are highly absorptive. This may be demonstrated by dissecting a fly which has fed on dyed sugar solution about twenty-four hours previously. The dyes (methylen blue or phenol red, usually) were often found concentrated in the crop, but never in the surrounding tissues: not only did they deeply color the walls of the mid-gut, but also the tissues adjacent to it.

Whether it is because the anterior region of the mid-gut is more permeable than other parts, or because this part of the digestive tract is long, the dyes seldom reach the posterior part, and even when the anterior third is highly stained, the remaining portion is generally almost free from coloring matter. At the same time, the malpighian tubules and hind-gut may be deeply colored. This indicates that materials in excess, or which are incapable of being metabolized, are often absorbed from the mid-gut only to be deposited in the malpighian tubules. This is, of course, a substantiation of the renal function of the tubules.

The function of the valve in the hind-gut is problematical. Graham-Smith cautiously suggests that it may destroy the remnants of the peritrophic membrane.

Wiggelsworth considers the rectal papillae organs which absorb excess water from the gut, but Graham-Smith doubts this. Another suggestion is that the papillae may oxidize toxic materials. This conclusion is wholly suppositive, and is based upon the rich tracheal supply of the papillae.

In a living fly the digestive organs are in constant motion. The lobes of the crop contract in rhythmic alternation. Waves of contraction pass anteriorly along the oesophagus from the crop to the proventriculus, which expands at intervals, usually concomitantly with the adjacent sphincter. Thus food passes into the mid-gut, along which waves of contraction pass posteriorly. A reverse peristalsis in the narrower part of the hind-gut probably serves to open the valve there. Strong, but irregular contractions occur in the rectal sack. Their effect is to move the rectal papillae inward and backward and then in a reverse direction, not synchronously, but cyclically.

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The Collection of Eggs of Aeschna multicolor (Hagen)

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As pointed out by Tillyard[1] and others, the rounded eggs of exophytic species of Odonata are easily collected. On the other hand, eggs of endophytic species have been laboriously obtained by examining masses of water weeds or by watching individual females in the act of ovipositing, and later taking the particular stem in which the eggs are observed to have been deposited.

A much simpler method has been developed by the writer as the result of a chance observation in 1943. During a casual stroll in the latter part of August in Pacific Grove, a copulating pair of *A. multicolor* were captured by hand and without injury. No papers being at hand, the separated individuals were placed in separate breast pockets of a loosely woven shirt. About fifteen minutes later it was noticed that the pocket containing the female glistened with about thirty eggs which had been oviposited through the cloth.

To obtain further eggs, a glass bowl full of tap water was covered with a piece of dish toweling, and the female held by the wing bases so that the tip of the abdomen was brought in contact with the wet towel. A large number of eggs were deposited through the cloth so that they were attached to the cotton fibers on the under side of the cloth by the pedicel and projected into the water at nearly right angles to the plane of the cloth. Nearly all of these eggs hatched between the 10th and 11th day.

During the summer of 1944, another copulating pair of *A. multicolor* was captured with a net. A modified procedure for obtaining eggs was developed which may have general application to endophytic species of Odonata, although it has not been tried on Zygoptera. The method may not be applicable to those species which remain paired during oviposition.

[1] Tillyard, R. J. The Biology of Dragonflies. 1917.

Construct an open-ended non-corrosive metal cylinder of slightly smaller outside diameter than the inside diameter of the vessel in which it is to be suspended. Cover the lower end of the cylinder with a piece of soft loosely woven cotton cloth. Three or four pins may be soldered onto the outside of the cylinder to support it in the vessel. Pour in tap water until the water level in the vessel is established at about ⅛ inch above the cloth.

Clip both pairs of wings of the captured female at about the level of the arculus with a pair of sharp scissors. Most Odonata can fly with all four wings clipped at the nodus. Place the female on the wet cloth. The diameter of the cylinder should be great enough so that freedom of movement is provided. The vertical walls of the metal cylinder must be high enough to prevent escape from the cloth surface. The 1944 specimen of *A. multicolor* treated in this manner deposited several dozen eggs, the majority of which hatched in from 14 to 20 days.

Unfortunately, the emergence of the pronymph was not observed in either of these cases. There seemed to be no effect on the success of emergence whether the cloth with attached eggs was maintained horizontal with eggs above or below, or with the cloth vertical.

Eggs were laid in a formless pattern, sometimes singly, and at others in compact groups. The reason for the difference in hatching rate between the 1943 and the 1944 pair is not known. Possibly it is related to water temperature.

Tillyard (loc. cit.) states that decaying vegetable matter is essential to the rearing of eggs. In both the collections herein described, ordinary city water was used. There was a slight amount of mold growth among the latest hatching eggs, and some may have been killed, but there was a high percentage of emergence. The larvae were active and fed readily on paramecium.

It would appear to be advisable to boil the cloth used, to remove any soluble material which would support mold growth, and to avoid cloth which has been starched or "sized."

Notes and News in Entomology

Under this heading we present from time to time short reviews, notes, news and comments on entomology throughout the world. Contributions from readers are solicited and will be acknowledged when used.

We commonly think of complete digestion occurring in the lumen of the alimentary tract before absorption into the blood. But this is not necessarily the case, and in some cases it seems possible that even proteins may be absorbed unchanged or in various states of degradation—both in insects and mammals. It is well known that numerous pigments occur in insects, and in at least some cases these would seem to be absorbed essentially as found. Lederer [1] in reviewing the distribution of pigments in invertebrates lists carotenoids, quinones, melanins, pterines, flavons (xanthones), bile pigments and chlorophyll derivatives as being found in insects. Although some of these may be formed by the insects, certainly a number of them are obtained from the food. For instance, chrysine (the yellow pigment of beeswax) is found in several plant resins and is probably derived directly therefrom by the bees.[2] And it is well known that the blood of certain caterpillars becomes colored from absorbed chlorophyll.

Particularly favorable material for the study of such absorption is supplied by the blood-sucking insects in which a large part of the ingested protein consists of hemoglobin. Wigglesworth [3] has recently presented a detailed analysis of the fate of hemoglobin in the blood-sucking tropical bug *Rhodnius prolixus* and a preliminary survey of it in various other blood-sucking arthropods.

Wigglesworth finds by exacting microspectroscopic methods that most of the ingested hemoglobin is broken down in the lumen of the gut of *Rhodnius*, the globin being absorbed and used as food, the hematin being excreted as protohematin. But a small amount seems to be absorbed into the blood with-

[1] Biol. Rev., **15**: 273–306. 1940. See also F. Mayer, The Chemistry of Natural Coloring Matters, 354 pp., Reinhold Publ. Corp., N. Y., 1943.
[2] R. Barre, Rev. Can. d. Biol., **1**: 485–490. 1942.
[3] Proc. Roy. Soc., **131B**: 313–339. 1943.

out digestion and circulates as kathemoglobin or some spectroscopically similar form. This circulating form of hemoglobin is taken up by the salivary glands and also by the yolk of developing eggs, both of which become colored red. Some is also taken up by the pericardial cells or nephrocytes, by the epithelial cells of the stomach and intestine, and on injection also by the Malpighian tubules. In these cells the red pigment is subsequently changed to brown, then green (verdohem?) and finally to the bile pigment biliverdin. The pericardial cells become bright green. The gut cells excrete the biliverdin, but free iron accumulates in these cells so that in old insects they are heavily laden with iron deposits.

The story is not the same for all blood-sucking arthropods. Wigglesworth reports that mosquitos and fleas do not absorb any of the blood pigments. They digest the hemoglobin almost completely and leave only a small residue of black protohematin in the feces. In lice (*Pediculus*), the bedbug (*Cimex*), various other Hemiptera, and ticks (*Ixodes, Ornithodorus*) varying amounts of pigments are absorbed but in no other species so readily as in *Rhodnius prolixus*. The bedbug and ticks break the absorbed pigment down to protohematin; only the louse and triatomids carried the breakdown on to the formation of bile pigments. Only in *Rhodnius* and *Cimex* do the salivary glands become colored red, and only in *Pediculus* and *Rhodnius* is hemoglobin transferred to the developing eggs.

These data on hemoglobin breakdown reemphasize the importance of the nephrocytes and especially the epithelial cells of the gut in the intermediary metabolism of insects. In passing we might remind readers that the loss of all of the hematsin would mean losing only 6% of the weight of the hemoglobin because approximately 94% of the weight of the molecule is in the readily utilizable globin. The fate of the hematsin part of the molecule is therefore likely not of great importance to the insect's economy.

Aside from these data presented by Wigglesworth, and the hemoglobins or erythrocruorins found as functional respiratory pigments in some chironomid larvae, hemoglobin has been re-

ported from a peculiarly sporadic listing of species. It is reported in *Gastrophilus* and certain aquatic Hemiptera (*Buenoa, Anisops* and *Macrocorixa*). In all of these, with the exception of the modified hemoglobin of chironomid larvae, the pigment seems to be a functionless inclusion derived from the blood of the host or prey. This explanation is least probable in *Macrocorixa* which is mainly, but not solely, herbivorous.

A. G. RICHARDS, JR.

Current Entomological Literature

COMPILED BY THE EDITORIAL STAFF.

Under the above head it is intended to note papers received at the Academy of Natural Sciences of Philadelphia and the University of Pennsylvania, pertaining to the Entomology of the Americas (North and South), including Arachnida and Myriopoda. Articles irrelevant to American entomology will not be noted; but contributions to anatomy, physiology and embryology of insects, however, whether relating to American or exotic species will be recorded.

This list gives references of the current or preceding year unless otherwise noted. Continued papers, with few exceptions, are recorded only at their first installment.

For records of Economic Literature, see the Experiment Station Record, Office of Experiment Stations, Washington. Also Review of Applied Entomology, Series A, London. For records of papers on Medical Entomology, see Review of Applied Entomology, Series B.

NOTE: The figures within brackets [ ] refer to the journal in which the paper appeared, as numbered in the List of Journals given at the end of the literature. The number of the volume, and in some cases, the part, heft, &c. is followed by a colon (:). References to papers containing new forms or names not so stated in titles are followed by (*); if containing keys are followed by (k); papers pertaining exclusively to Neotropical species, and not so indicated in the title, have the symbol (S).

Papers published in ENTOMOLOGICAL NEWS are not listed.

GENERAL—The status of names published as manuscript names [87] 1: 103–14. Status of certain pre-Linnean names reprinted subsequent to 1757 [87] 1: 115–26. On the type of a genus "A" containing two sps. "Ab" and "Ac," where the generic name in question was published on, or before 31st Dec. 1930 [87] 1: 127–38. Suspension of the rules for Vanessa Fab., 1807 [87] 2: 239–50. On the principles to be observed in interpreting Art. 8 of the Code in relation to the form in which gen. & subg. names are to be published [87] 3: 13–24. **August Busck**, 1870–1944—Obituary and bibliography by Heinrich and Loftin. [10] 46: 232–39, portrait. **Brett, G. H.**—Electrically operated regulated humidity control. [12] 37: 552–53, ill. **Brues, C. T.**—Fluorescent staining of insect tissues. [68] 100: 554–55. **Essig, E. O.**—Needed changes in teaching entomology. (Editorial) [12] 37: 563–65. **Frisch, K. v.**—Christian Kon-

rad Sprengels Blumentheorie vor 150 Jahre und Heute. [Naturwiss.] 31: 223–29 (1943). **Gressitt, J. L.**—Entomology in war-torn China. [68] 100: 519. **Hatward, K. J.**—Primera lista de insectos tucumanos perjudiciales. Primer Suppl. [Estacion Exper. Agr. Tucuman, Pub. Miscel.] 1944 (4): 32 pp. **Maurice Cole Tanquary,** 1881–1944. Obituary by W. A. Riley. [68] 100: 539–40. **McCoy, O. R.**—Malaria and the war. [68] 100: 535–39. **Munger, F.**—An adaptation of a thermograph to regulate variable temperature. [12] 37: 554. **Wadley & Wolfenbarger**—Regression of insect density on distance from center of dispersion as shown by a study of the smaller European bark beetle. [47] 69: 279–88. **William, C. B.**—Some applications of the logarithmic series and the index of diversity to ecological problems. [Jour. Ecol.] 32: 1–44. **William Williams Henderson,** 1879–1944—Obituary. [68] 100: 583–84.

ANATOMY, PHYSIOLOGY, MEDICAL—Arthur, D. R.—Aphidius granarius in relation to its control of Myzus kaltenbachi. [22] 35: 257–70, ill. (Braconid). **Barnes, O. L.**—Feeding experiments with the range caterpillar egg parasite Anastatus semiflavidus. [12] 37: 544–45. **Birch & Andrewartha**—The influence of drought on the survival of eggs of Austroicetes cruciata in S. Australia. [22] 35: 243–50. **Clarke, C. H. D.**—A positive pyrotropism (in horntails). [Canad. Field Nat.] 58: 142. **Cornman, I.**—Effects of ether upon the development of Drosophila melanogaster. [23] 17: 367–77. **David, Bracey & Harvey**—Equipment and method employed in breeding Aedes egypti for the biological assay of insecticides. [22] 35: 227–30. **Dethier, V. G.**—Observations on the life history of Cucullia asteroides (Noctuid). [4] 76: 161–62. **Dowdy, W. W.**—The influence of temperature on verticle migration of invertebrates inhabiting different soil types. [84] 25: 449–60. **Evans, A. C.**—Observations on the biology and physiology of wireworms of the gen. Agriotes. [20] 31: 235–49. **Frisch, K. v.**—Versuche uber die Lekung des Bienenfluges durch Duftstoffe. [Naturwiss.] 31: 445–60 (1943). **Haardt, K.**—Über die Ausprägungsweise und Ausprägungsbedingungen der Mutation kfl (Kruzflügelig) bei Ephestia kühniella. [Biolog. Zentralb.] 63: 478–87 (1943). **Imms, A. D.**—On the constitution of the maxillae and labium of Mecoptera and Diptera. [53] 85: 73–96, ill. **Kühn & Engelhardt**—Uber zwei Entschuppung bewirkende Mutationen (Vi und cal) bei Ptychopoda seriata. [Biolog.

Zentralb.] 63: 470–78 (1943). **McGovran, Yeager, Mayer & Munson.**—Effect of potassium fluoride and pyrethrum on Periplaneta americana after hemocytes are blocked with Chinese ink or nephrocytes are stained with trypan blue. [7] 37: 414–19, ill. **Munson & Yeager.**—Fat inclusions in blood cells of the southern armyworm, Prodenia eridania. [7] 37: 396–400, ill. **Noland, J. L.**—Improved method for the determination of the lethal temperature of insects, with especial reference to studies on Periplaneta americana. [Proc. Indiana Acad. Sci.] 53: 186–87. **Piepho, H.**—Wirkstoffe in der Metamorphose von Schmetterlingen und anderen Insekten. [Naturwiss.] 31: 329–35 (1943). **Ribbands, C. R.**—Influence of rainfall, tides and periodic fluctuations on a population of Anopheles melas. [22] 35: 271–95. **Robertson, F. W.**—Removal of insect pests from stored products by means of behavior stimuli. [22] 35: 215–17. **Slifer, E. H.**—Ileal caeca in the Eumastacidae (Orthoptera). [7] 37: 441–46, ill. **Simmonds, F. J.**—Propagation of insect parasites on unnatural hosts. [22] 35: 219–26. **Smith, F.**—Nutritional requirements of Camponotus ants. [7] 37: 401–8. **Vogt, M.**—Induktion von Metamorphoseprozessen durch implantierte Ringdrüsen bei Drosophila. [Roux' Arch. f. Entwickl. des Organismen] 142: 131–82 (1942). **Vogt, M.**—Zur Produktion gonadotropen Hormones durch Ringdrüsen des ersten Larvenstadiums bei Drosophila. [Biolog. Zentralb.] 63: 467–70 (1943). **Wellington, W. G.**—Barotaxis in Diptera, and its possible significance to economic entomology. [31] 154: 671–72. **Yeager & Munson**—Relation of dosage to survival time of arsenite-injected roaches. [68] 100: 501–03.

ARACHNIDA AND MYRIOPODA—Chamberlin & Ivie.—Spiders of the Georgia Region of N. Amer. [Bull. Univ. Utah] 35: (9), 267 pp., ill. (*). **Mello-Leitao, C. de.**—Comentarios a respeito da possivel filogenia dos opilioes. [15] 16: 197–209, ill. **Robertson, P. L.**—Technique for biological studies of cheese mites. [22] 35: 251–55, ill.

THE SMALLER ORDERS—Borror, D. J.—Additional notes on Erythrodiplax maculosa. [7] 37: 393–95, ill. **Daggy, R. H.**—Two mayfly gynandromorphs. [10] 46: 256–59. **Dos Santos, N. D.**—Description of the male of Erythrodiplax maculosa. [7] 37: 389–92, ill. **Imms, A. D.**—(See under anatomy.) **Montgomery, B. E.**—Distribution and relative seasonal abundance of the Indiana sps. of Agrionidae (Odonata) (Abstract). [Proc. Indiana Acad.

Sci.] 53: 179–85. **Wright, M.**—Some random observations on dragon fly habits with notes on their predaceousness on bees. [49] 19: 295–301. **Taub, R.**—New No. Amer. fleas. [Zool. Ser. Field Mus. N. H.] 29: 211–20.

ORTHOPTERA—Birch & Andrewartha—(See under Physiology.) **Noland, J. L.**—(See under Anatomy.) **Slifer, E. H.**—(See under Anatomy.) **Williams, C. B.**—(See under General.)

HEMIPTERA—Bugbee, R. E.—Eleven n. sp. of Eurytoma from Mexico. [7] 37 420–38, ill. **DeLong, D. M.**—New gen. (Tenucephalus) and species of Mexican leafhopper related to Parabolocratus. [43] 44: 236–37, ill. **Essig, E. O.**—New aphid on guayule and notes on other species of Cerosipha. [Hilgardia] 16: 177–84, ill. **Funkhauser, W. D.**—Some Venezuelan Membracidae. [18] 29: 193–94. **Hungerford, H. B.**—Some Venezuelan aquatic Hemiptera. [18] 29: 129. **Knull, D. J.**—Notes on leafhoppers with descriptions. [43] 44: 239–42, ill. **Lawson, C. A.**—Relation of hind tibial and sensoria to intermediacy in parthenogenetic aphids. [7] 37: 409–13. **Muesebeck, C. F. W.**—Genus Ollarianus in No. Amer., including Mexico (Cicadel). [91] 34: 391–98, ill. (*). **Smith, R. H.**—Bionomics and control of the nigra scale, Saissetia nigra. [Hilgardia] 16: 225–88, ill. **Usinger, R. L.**—Nomenclature of the genus Nysius and its allies (Lygaeid). [10] 46: 260–62.

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